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Seaweed farming: A potential source for the sustainable blue economic development in Algeria

Bougueroua Mariem[1]

[1] Laboratory of Industrial Policies and Development of Extrenal Exchanges, University of, Mostaganem (Algeria).

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Abstract:

Seaweed farming and exploitation have seen rapid growth in certain countries, while over 150 coastal nations, including Algeria, have yet to explore the potential of developing a seaweed industry. This article presents new research on the potential benefits of seaweed exploitation in Algeria within the framework of sustainable economic development. Using a SWOT analysis, we examine the strengths, weaknesses, opportunities, and threats associated with seaweed farming in Algeria, addressing the three pillars of sustainable development: environmental, economic, and social dimensions. Our findings demonstrate that seaweed cultivation and exploitation are key drivers for the development of the blue economy in Algeria and can contribute significantly to achieving the country's sustainable development goals (SDGs). The study also outlines the processes involved in the cultivation, processing, and commercialization of seaweed for economic purposes. Establishing a new industrial sector for seaweed exploitation, which requires minimal technological infrastructure, can promote socio-economic development, diversify the national economy, and foster long-term sustainability.

Keywords: *Seaweed; Blue economy; Sustainable development; SWOT analysis; Algeria.*

Jel Classification Codes : *O13 ; O14 ; Q56*

Corresponding Author: *BOUGUEROUA Mariem, meriem.bougueroua@univ-mosta.dz*

1. Introduction

Sustainable development and environmental protection have become major priorities in the development policies of many countries. The focus on the concept of sustainable development received widespread attention after the introduction of the Sustainable Development Goals (SDGs) agenda by the United Nations Development Program (UNDP) in 2015. This development approach places emphasis on economic growth while simultaneously protecting the environment and ensuring its preservation for future generations (Dissanayake et al., 2021). Furthermore, it should be noted that the green economy is a key element of sustainable development, offering pathways to achieve economic prosperity, environmental protection and social equity in a holistic and integrated way (Dogaru, 2021; Chaaben, et al., 2022). The United Nations Environment Program (UNEP) highlights the crucial role of the green economy and sustainable development in addressing major global challenges such as climate change, biodiversity loss, and social inequality. The transition to a green economy requires a significant investment in technology, infrastructure and human capital. It has prompted researchers to look beyond the green economy and consider the presence of another vast reservoir of natural resources, such as the oceans (BARI, 2017; Choudhary et al, 2018).

Indeed, while the green economy is a promising path to sustainability, it is essential to recognize the importance of the blue economy as a complementary element in achieving sustainable development goals. Overall, the blue economy complements and reinforces the green economy by expanding resource options. The blue economy shares a common goal with the Rio +20 green economy initiative, aiming for “enhanced human well-being and social equity, alongside notable reductions in environmental risks and ecological scarcities" (UNEP, 2011). According to the World Bank (2017), the blue economy refers to the sustainable use and management of ocean resources and ecosystems to promote economic growth, improve livelihoods, and preserve marine environments for present and future generations. It encompasses a wide range of economic activities and sectors, including fisheries, aquaculture, marine tourism, renewable energy, biotechnology, shipping, and coastal development.

As an emerging sector, seaweed farming is considered as a promising solution for the development of the blue economy, offering sustainable food, feed, fuel, and various other products and services. Indeed, over 140 species are used for food production worldwide, which is considered a profitable source in the market. In addition, seaweeds provide several Ecological, Social, and Economic Advantages (Jagtap and Surya, 2022).

Currently, global seaweed production stands at 35.8 million tons, primarily from aquaculture, representing 97% of the total output, with a market value of US$ 11.8 billion (Sultana et al., 2023). In many countries, activities linked to the exploitation of seaweed, both industrial and food, are developing and taking their place immediately after fishing as a source of employment and income, for the populations living along the coast. Indeed, Seaweed aquaculture production in Africa, led predominantly by women, has improved the livelihoods of its coastal people.

Despite the global expansion of seaweed farming and its significant economic and social benefits, Algeria has yet to develop an organized and large-scale seaweed industry. Given its vast coastline and growing demand for marine resources, the question arises: **what are the opportunities and challenges in establishing a sustainable seaweed farming industry in Algeria, and how can it contribute to sustainable development of blue economy?**

This study aims to analyze the potential of seaweed farming in Algeria as a driver of economic diversification and sustainable development. It will explore the strengths, weaknesses, opportunities and challenges of this activity.

To achieve this, we test the following hypotheses:

- The development of a seaweed aquaculture industry in Algeria can significantly contribute to contribute to sustainable development of blue economy, by creating new jobs and generating income for coastal populations.
- Success in establishing seaweed aquaculture in Algeria depends on overcoming important challenges, such as regulatory frameworks, technological gaps and market integration.

2. Background on Sustainable Blue Economy

The concept of the Blue Economy (BE) has gained prominence as a strategy for ensuring the sustainable use of ocean and water resources while balancing economic growth and environmental protection. However, there are inherent conflicts between economic development and the conservation of marine ecosystems, necessitating solutions that align with global initiatives like the United Nations' Sustainable Development Goals (SDGs). Despite its significance, defining the scope of the BE in relation to the SDGs remains challenging, particularly in identifying key stakeholders and their roles.

A literature review covering the period from 1998 to 2018 reveals that the BE is most closely linked with SDGs 14 (Life Below Water) to 17 (Partnerships for the Goals). Interestingly, stakeholders tend to prioritize SDG 3 (Good Health & Well-Being) and SDG 8 (Decent Work & Economic Growth) in the BE context. Given the variations in stakeholder involvement, their roles in advancing BE-SDGs objectives can be direct or indirect (Lee & Khim, 2020).

For a comprehensive approach, sustainability must be understood as a multifaceted concept that spans three interconnected dimensions: ecological, economic, and social sustainability. These dimensions must be addressed simultaneously to ensure the long-term viability of marine ecosystems while promoting societal well-being and economic development.

Ecological sustainability focuses on maintaining the health of marine ecosystems and preserving biodiversity. It entails managing natural resources in a way that does not exceed the environment’s capacity to regenerate, ensuring the continuity of essential ecosystem services.

Economic sustainability is centered on the ability of marine industries to continue providing goods and services without depleting the ocean’s resources or causing long-term damage to the environment. It focuses on creating economic value through the responsible use of marine resources, such as: sustaining marine tourism and sustainable fisheries and aquaculture.

Social sustainability focuses on the well-being and equity of communities that depend on marine resources. It ensures that the benefits of marine conservation and economic activities are shared equitably, and that the livelihoods of local populations are improved.

3. Blue economy in Algeria

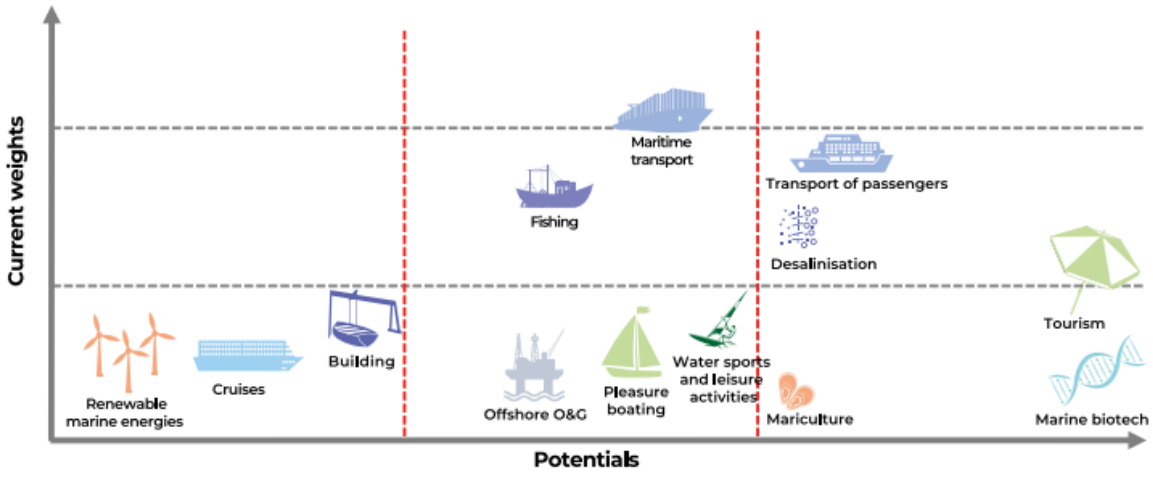
3.1 An overview of Algeria's maritime and coastal resources

The socio-economic importance of the blue economy is becoming increasingly pronounced in Algeria. In 2018 in Algiers six priorities were agreed upon by the Ministers of the Western Mediterranean (WestMED) countries together with the European Commission and the Union for the Mediterranean, in order to establish a common roadmap for the development of a sustainable blue economy in the Western Mediterranean area (Coletti, 2022).

At the WestMED regional conference on the blue economy, the ministry responsible for fisheries and aquaculture estimated that activities and services linked to the sea and coastal areas contribute at least 20% to the national GDP. With fifteen million Algerians living in coastal wilayas and around 67% of industrial activities concentrated in northern Algeria, coastal regions play a central role in the country's economic landscape. In addition, around seven million Algerians depend directly or indirectly on the sea for their livelihood. According to the Ministry of Fisheries and Fish Production (2021), the marine and maritime sectors currently employ nearly 300,000

people directly and around 450,000 indirectly. However, Algeria's coastline, estimated at 1,620 km is being used intensively for urban development, tourism and industry. Indeed, more than 60% of the most polluting activities are concentrated on the coasts. The development of the blue economy in Algeria is linked to the potential of the country's maritime and coastal capital. Figure 1 shows some of the key areas where Algeria can capitalize on its blue economy:

Figure (1):Socioeconomic Impact of Blue Economy Sectors.



The Source: Ministry of Fisheries and Fish Production, 2021.

3.2 Exploitation of Seaweed in Algeria

The economic significance of seaweed has evolved considerably, positioning it as a strategic resource with diverse industrial applications. It is a major source of hydrocolloids, such as agar-agar, carrageenans, and alginic acid, which can be efficiently extracted through simple hot-water processes. These compounds possess gelling and stabilizing properties, making them essential in

industries such as food processing, cosmetics, pharmaceuticals, and textiles (Sultana, 2023).

Beyond its industrial applications, seaweed offers significant nutritional and health benefits, supplying essential vitamins, minerals, and antioxidants, while also serving as a valuable calorie source (Tiwar, 2015). Unlike terrestrial crops, seaweed cultivation does not compete for arable land, allowing agricultural and forestry activities to continue unimpeded. Moreover, since seaweed grows in marine environments, it does not require freshwater or additional nutrients, unlike conventional crops.

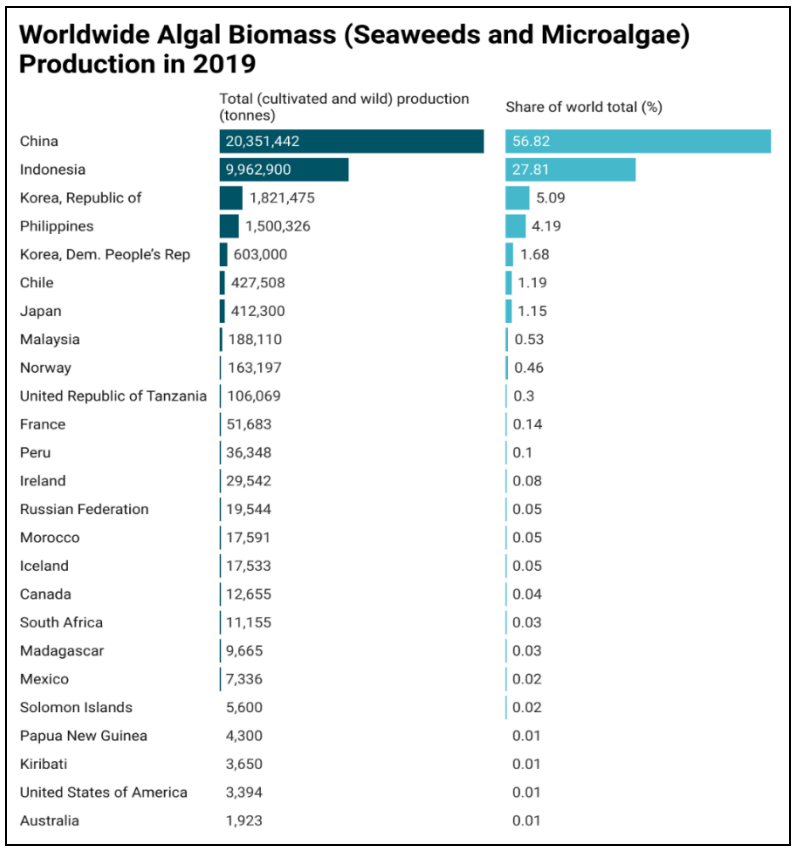
With the global population expected to reach 9 billion by 2050, current food production systems are projected to meet only half of this demand (FAO, 2021). This underscores the necessity of identifying alternative food sources and enhancing food security. The high nutritional value of seaweed aligns with this growing demand, positioning it as a viable supplementary food base.

Additionally, seaweed plays an emerging role in renewable energy, particularly in the production of biofuels, known as macroalgae-based biofuels (Adeniyi et al., 2018). This further enhances its economic and environmental value, reinforcing its importance within a sustainable blue economy.

According to the Food and Agriculture Organization of the United Nations, (2021), the global production of seaweed has undergone significant changes over the years. There is a notable regional imbalance in Seaweed production, with Asia dominating the scene.

In 2019, Asia accounted for 97.4% of the world's seaweed production, of which 99.1% came from cultivation. Countries in East Asia and Southeast Asia occupy seven out of the top ten positions in seaweed production. In contrast, the Americas and Europe contributed only 1.4% and 0.8% of the global algae production in 2019, respectively. Africa relies more on cultivation, with 85.3% of its algae production coming from cultivation. However, its contribution to global algae production is relatively low at 0.4% (*cf. Figure 02*). Overall, the shift towards aquaculture-based algae production has been remarkable, with Asia leading the way. Other regions such as Africa and Oceania also heavily rely on cultivation, although their global contribution is smaller. The Americas and Europe primarily depend on wild harvesting, resulting in a regional imbalance in algae production.

Figure (2) : The main countries producing aquatic plants, including seaweeds, in world (2019).



The source: Author, based on Data source of the FAO, 2021.

The study on introduced species along the Algerian coast (Grimes et al., 2018) reveals a significant presence of non-native marine organisms, with a total of 70 introduced species recorded between 1834 and December 2017. These species are categorized as:

- 55.7% true aliens
- 25.7% range-expanding species
- 15.7% cryptogenic species
- 2.9% vagrant species

Fish and macroalgae dominate the group, accounting for 38.57% and 30% of the introduced species, respectively. A total of 348 introduction events have been reported, with 64.9% of these linked to macroalgae, and 50% of sightings occurring in the central region of Algeria.

In terms of establishment, 20% of the introduced species have become established along the Algerian coast. Notable established species include the macroalgae Codium fragile and Ulva lactuca, as well as the cryptogenic species Oculina patagonica. Additionally, species such as Asparagopsis armata, A. taxiformis, and Caulerpa cylindracea are considered invasive.

The study highlights the need for ongoing research to understand the mechanisms behind the spread of these species, particularly in the southwestern Mediterranean. The table 1 indicates the possibilities of use, and the characteristics of the various species of algae listed in Algeria.

Table (1): Potential applications and characteristics of seaweed species identified in Algeria.

Seaweeds						
Color	**Red**		**Green**		**Brown**	
Some Algerian spices	*Asparagopsis taxiformis* 	*Ellisolandia elongate* 	*Ulva Lactuca* 	*Ulva Rigida* 	*Asperococcus Bulbosus* 	*Fucus* 
Common uses	**Food**		**medicinal**		**Bioactive functions**	
	Agar, Essence, Rice wraps, Side dish, Snacks, Soup.		Diabetes, Diarrhea, and colitis, Hangovers High blood pressure, Rheumatism, Stomach disorders, Sunstroke, Urinary diseases.		Antioxidant, Anticancer, Anti-diabetic, Anti-coagulant, Anti-inflammation, Anti-microbial, Immunomodulation.	

The Source: Author

The floristic composition of Algerian Seaweed highlights several species of economic interest, belonging to different taxonomic classes, which could be considered for future commercial exploitation as part of development projects in the algal sector. The classification presented in Table 1 is based on the potential uses and industrial applications of the various algal species identified in Algeria, taking into account their availability in sufficient quantities.

According to Bouidjra et al. (2010), Rhodophyceae (Bangiophyceae, Florideophyceae) represent a particularly promising resource, with an average coverage rate of 64% in spring, highlighting their high potential for exploitation. They are followed by Chlorophyceae and Bryopsidophyceae, which reach an average coverage rate of 16% in summer, while Phaeophyceae maintain a 20% coverage rate throughout the year. The latter group is especially significant due to the presence of perennial species from the genus Systoseira, whose dry biomass averages 270 g/m² for two key species (Systoseira stricta and Systoseira crinita), both valued for their high alginate content.

4. SWOT Analysis of seaweed farming in Algeria

SWOT analysis is a qualitative analysis approach, which operates on the logic of optimizing strengths and opportunities while concurrently addressing and mitigating weaknesses and threats, for an organization or a strategic plan (Phadermrod, 2019). The SO (Strengths and Opportunities) strategy aims to enhance the value of elements related to strengths and opportunities within the strategy. The WO (Weaknesses and Opportunities) strategy seeks to capitalize on opportunities while addressing weaknesses that are interconnected with the strategy. The ST (Strengths and Threats) Strategy focuses on leveraging strengths while addressing threats associated with the strategy. Finally, the WT (Weaknesses and Threats) strategy aims to mitigate weaknesses and counteract threats that are interrelated with the strategy.

In addition, the SWOT analysis is composed of internal and external assessments. The internal assessment is conducted to illustrate the strengths and weaknesses of an organization or a strategic plan; the external assessment is applied to discover opportunities and threats. Strengths stand for any available resources that can be used to advance the performance. Weaknesses are flaws, which may decrease competitive advantages, efficiency, or financial resources. Opportunities are external changes that could contribute to an additional development and threats are outside factors that may cause problems.

The main advantage of SWOT analysis is its application simplicity and its ability to solve a wide range of business problems, whereas the main disadvantage results in no opportunity to rank significance of one factor versus another. Nevertheless, SWOT analysis is an appropriate tool to address wide range of business issues and therefore is widely practiced (Yuan, 2013).

4.1 Internal Factor Analysis

At the environmental level, one of the main strengths is the abundance of seaweed resources along the Algerian coast, offering significant potential for sustainable exploitation. Additionally, Algeria possesses favorable marine conditions that can support the development of seaweed farming, which would ensure a steady supply for both local and international markets while contributing to marine ecosystem preservation. However, a major weakness is the limited knowledge and research on Algeria's marine biodiversity, particularly regarding the taxonomy, distribution, and biomass of native seaweed species. This lack of scientific data hinders the efficient management and sustainable utilization of these resources.

At the economic level, the seaweed industry presents a valuable opportunity for diversifying the Algerian economy through the development of high-value green products, such as agar, carrageenan, and alginates, which are widely used in the food, pharmaceutical, and cosmetic industries. Moreover, this sector has the potential to become a significant source of employment and revenue, supporting local communities, especially in coastal regions. However, current investment in the sector is largely limited to research activities, with little focus on innovation and industrial-scale production. The absence of well-developed infrastructure and industrial processing facilities further limits the commercialization of seaweed-based products.

At the social level, the seaweed industry can play a crucial role in job creation, particularly for women and coastal communities, who could be actively involved in seaweed farming, harvesting, and processing. Additionally, the production of seaweed-based health and wellness products could

contribute to improving public health and enhancing food security. However, a major challenge is that the seaweed harvesting sector remains unstructured and informal, with no clear regulatory framework to govern its operations. Furthermore, there is a lack of technical expertise and training programs, making it difficult for local entrepreneurs and workers to fully integrate into this emerging industry.

To unlock the full potential of Algeria's seaweed sector, it is essential to invest in marine research, technological innovation, and industrial development, while also implementing effective policies to support sustainable exploitation and long-term economic growth.

4.2 External Factor Analysis

One of the global opportunities for Algeria's seaweed farming is the decreasing quality of seaweed production in parts of Asia due to water pollution and environmental degradation. As a result, global markets are increasingly seeking alternative sources of high-quality seaweed, which Algeria could capitalize on by developing a sustainable and environmentally friendly seaweed sector.

At the economic level, the establishment of a seaweed farming presents a strategic opportunity to diversify the national economy, moving beyond reliance on hydrocarbons. The production of high-value-added products, such as agar, carrageenan, bioactive compounds, and biofuels, could open new domestic and international market opportunities. Moreover, this sector could act as a compound for innovation, fostering collaborations between universities, technical institutes, and industrial stakeholders. Strengthening these research-industry links would not only support technology transfer but also drive product development and commercialization.

Additionally, the development of seaweed farming aligns with global trends in the blue economy, supporting sustainable marine resource exploitation while generating employment opportunities, particularly for coastal communities and women. It also contributes to climate change mitigation, as seaweed cultivation absorbs carbon dioxide, enhances marine biodiversity, and serves as a natural coastal protection against erosion.

Despite its promising potential, the seaweed sector in Algeria faces significant challenges that could hinder its development. One of the primary economic threats is the low level of investment in this emerging sector. Limited access to financial support, infrastructure, and processing facilities makes it difficult to transition from research and small-scale activities to industrial-scale production. Additionally, bureaucratic barriers and complex regulations related to obtaining licenses for marine farming pose significant obstacles for entrepreneurs and investors.

Another critical threat is coastal tourism development, which, if not managed sustainably, could lead to marine habitat degradation and limit the availability of suitable areas for seaweed farming. Unregulated tourism activities, combined with increasing marine pollution and habitat destruction, could negatively impact wild seaweed populations and cultivation zones.

Furthermore, unsustainable harvesting practices pose a major risk to the long-term viability of the sector. Overexploitation of natural seaweed beds without proper management measures could deplete marine ecosystems, reduce biodiversity, and disrupt the ecological balance. Establishing clear regulations, monitoring systems, and responsible harvesting guidelines will be essential to

prevent environmental damage and ensure the sustainability of seaweed exploitation in Algeria. The following table summarizes the SWOT analysis for seaweed farming in Algeria (Table 2).

Table (2) :Summarise of the SWOT analysis

Internal Factor Analysis	
Strengths (+)	**Weaknesses (-)**
❖ **Environment level** ▪ Important Potential for seaweed of commercial interest ▪ Favorable natural and climatic conditions. ▪ Geographical location of the country ❖ **Economic level** ▪ Development of new green products. ▪ Diversification of the national economy. ▪ Considerable source of revenue. ▪ Low capital investment. ❖ **Social level** ▪ Diversity of jobs potentially generated. ▪ Equal opportunities for women and men. ▪ Low labor costs. ▪ Significant income for rural communities.	❖ **Environment level** ▪ Limited knowledge of marine resources specially seaweeds. ▪ Development of coastal tourism. ❖ **Economic level** ▪ New and unstructured sector. ▪ Limited investment. ❖ **Social level** ▪ limitation of specialized manpower in terms of seaweed cultivation. ▪ Difficulties and recurrent barriers to obtain areas at sea to be exploited.
Extrenal Factor Analysis	
Opportunities (+)	**Threats (-)**
• **Environment level** • Deterioration of water quality in Asia. • Innovation and research • **Economic level** • International support for blue economy. • Access to global funds on blue initiatives. • High global demand for seaweed products. • Few competitors in Africa. ❖ **Social level** • International support for blue economy. • Growing awareness of the benefits of seaweed.	• **Environment level** • Impacts of climate change on ecosystems. • **Economic level** • Morocco is ranked the 5th exporter in the world. ❖ **Social level** • Overexploitation.

5. Conclusion:

The blue economy offers real prospects for leading the national economy's transition to a sustainable economy. Indeed, the transition to a blue economy can make a clear contribution to food security, energy transition and citizens' well-being. According to the Ministry of Fisheries and Fisheries Production, the investments mobilized and planned in Algeria's priority blue economy sectors should boost GDP in several sectors.

The results of this study show that the potential exploitation of seaweed in Algeria will be an important source of employment and income, especially for people living along the coast. The Algerian Coast offers an excellent prospect for the cultivation of seaweeds, due to the favorable environmental conditions and the availability of several species. We have shown that the exploitation and cultivation of seaweed will contribute significantly to the development of the country’s blue economy. With a coastline of more than 1600 km, the implementation of projects for the efficient exploitation of marine resources in Algeria is more than desirable.

In addition, with the large number of algae species estimated in Algeria, the seaweed industry is more than promising. The implementation of this industry, which requires very few resources, promotes the socio-economic development of the country and contributes to the diversification of the national economy. By implementing best practices in seaweed cultivation, companies can set up successful operations and contribute to the growth of the seaweed industry and the development of the country's blue economy

Finally, by intensifying and developing efforts in seaweed cultivation and utilization, Algeria can join other African countries as a world leader in the production, processing and consumption of a wide variety of seaweeds.

The study concludes that the exploitation and cultivation of seaweed can contribute to the achievement of the sustainable development goals in Algeria.

For this purpose, we can suggest the following few recommendations:

- Developing scientific and technical research on algae resources in Algeria.
- Developing the culture of seaweeds among citizens.
- Promoting regional co-operation to benefit from their experience.

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